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ORIGINAL ARTICLE

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Urinary cotinine concentration in flight attendants, in relation to exposure to environmental tobacco smoke during intercontinental flights

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Abstract ***Objectives:*** To measure and compare the urinary cotinine concentration (U-cotinine) in non-smoking cabin attendants (C/A) working with the Scandinavian Airlines System, before and after work on intercontinental flights with exposure to environmental tobacco smoke (ETS). ***Methods:*** The study material consisted of 24 cabin attendants and one pilot, all volunteers and all without exposure to ETS in the home, working on 15 intercontinental flights. Information on age, gender and occupation was gathered, as well as possible sources of ETS exposure in other places, outside work and during previous flights, during a 3-day period prior to the investigation. Urine samples were taken before departure and after landing, on board, and were kept frozen (−20 °C) until analysis. Cotinine was analyzed by a previously developed gas chromatographic method, using mass spectrometry (MS) with selected-ion monitoring (SIM). The difference in U-cotinine before and after the flight was compared. Moreover, the change in U-cotinine during the flight was related to occupation (work in the forward or aft galley) and observed degree of smoking during each flight. ***Results:*** The median U-cotinine was 3.71 μg/g crea; 2.4 μg/l (unadjusted) (interquartile range 2.08–8.67 μg/g crea) before departure, and 6.37 μg/g crea; 7.1 μg/l (interquartile range 3.98–19 μg/g crea) after landing, a significant difference ($P < 0.003$). C/A in the aft galley had a significantly higher concentration of U-cotinine after landing than subjects working in the front of the aircraft ($P = 0.01$). In C/A working in the aft galley, the median increase of U-cotinine was 3.67 μg/g crea; 3.2 μg/l (interquartile range 0.04–13.8 μg/g crea) during flight. In contrast, those seven subjects working in the forward part of the aircraft had no increase in U-cotinine during the flight (median increase 0.97 μg/g crea; 0.5 μg/l interquartile range 0.27–2.65 μg/g crea). ***Conclusion:*** Tobacco smoking in commercial aircraft may cause significant exposure to environmental tobacco smoke among C/A working in the aft galley, despite high air exchange rates and spatial separation between smokers and non-smokers. This agrees with earlier studies, as well as measurements on the aircraft, showing a higher degree of ETS-related air pollution in the aft galley than in the forward galley. The average cotinine concentration in urine was similar to that in other groups with occupational exposure to ETS, e.g., restaurant staff, police interrogators and office workers. Since smoking in commercial aircraft may result in an involuntary exposure to ETS among non-smokers, it should be avoided.

Key words Nicotine · Cotinine · Aircraft · Commercial airline crew · Aerospace medicine · Environmental tobacco smoke · Indoor air quality

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Introduction

The future growth of aircraft transportation on a global basis is estimated at 5% per year [16], and worldwide nowadays more than 1,000 million people are transported by aircraft annually [24]. Many have the aircraft cabin as their work environment. The number of commercial cabin attendants (C/A) in the world is 250,000, each spending an average work time of about 900 h per year in aircraft [15].

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The concern about environmental tobacco smoke (ETS) as a workplace hazard has increased during the past decade, mainly because of the increased risk of lung cancer and cardiovascular problems [35]. In addition, ETS exposure may affect asthmatic people [6] and cause ocular and nasal effects among passengers and C/A in aircraft [19, 21], and can be the cause of "sick building syndrome" [17, 25, 26, 34]. The cabin in commercial aircraft is densely populated, and exposure to ETS may occur if smoking is allowed [5, 8, 9, 21, 22, 23, 24]. The exposure to ETS on commercial passenger flights is today a debated issue. In aircraft, smoking and non-smoking passengers are usually separated into different sections to reduce the risk of involuntary ETS exposure. Air movements in the aircraft in combination with return air systems may, however, cause involuntary ETS exposure on board. Some measurements of ETS exposure among passengers are available [9, 21, 22, 23], but few investigations are available where the degree of ETS exposure among C/A has been studied by biological monitoring [11].

Tobacco contains nicotine, which is metabolized to the main metabolite cotinine [2]. This compound is nowadays widely used as a specific biological marker of exposure to tobacco smoke [13]. Nicotine has a short half-life in biological tissues, and is therefore a measure only of very recent exposure to ETS [10, 13]. In contrast, cotinine has a long biological half-life (about 18 h), and can be determined in plasma or serum [30], in urine [13, 34], in saliva [4] and in hair [7]. Measurement of cotinine in urine has been used to quantify ETS exposure among adult non-smokers both in the home environment [20, 29, 31, 33] and in work environments, e.g., bars and restaurants, the police force, and in offices [12, 14, 18, 32]. Some earlier investigations have studied cotinine excretion in urine in aircraft passengers [21], but little is known about urinary cotinine concentration (U-cotinine) among non-smoking C/A and pilots.

The aim of our study was to measure and compare U-cotinine in non-smoking C/A, before and after work on intercontinental flights with exposure to ETS.

Subjects and methods

The investigation was performed as a part of a larger project on hygienic and medical aspects of the cabin air quality during intercontinental commercial flights.

Subjects

All investigations were made in the same type of aircraft, operated by the Scandinavian Airlines System (SAS). On each flight, there are always seven C/A and three pilots in-flight. The Purser, stewards and one air hostess(-host) work mostly with forward passengers based in the forward galley. The other three C/A work with passengers based in the aft galley. All C/A and flight deck crew on 15 intercontinental flights were informed of the project. Non-smoking C/A living in dwellings without any active smokers were invited to participate in the study. The study was performed from November 1995 to March 1997, in association with routine hygiene measurements on board. The study material consisted of 24 voluntary C/A and one pilot. Pilots were not invited to the study, but one flight officer requested to participate because of the irritating symptoms from ETS exposure on the flight deck.

In connection with the urine sample collection on board, information was gathered on personal characteristics, including smoking habits, use of snuff or nicotine chewing gum, and possible exposure to ETS in different locations during a 3-day period prior to the investigation. Information on ETS exposure on earlier flights during the previous 5-day period was gathered from current crew schedules. During the study period, smoking was allowed on all intercontinental flights and longer European flights, but prohibited on all flights within Scandinavia and between Scandinavia and European destinations north of the Alps. Information on the number of passengers was gathered from the passenger lists, and occurrence of smoking on board was observed by the occupational hygienist performing the investigation. Smoking on board was crudely classified into three categories: few smokers (< 20), normal number of smokers (20–30), and many smokers (> 30). In addition, information on occupation and workplace location during the flight (forward galley, aft galley or both) was gathered for each individual.

Urine samples were obtained on board, before departure and after landing, and were kept frozen (−2 °C) until analysis. Cotinine (CAS no. 486-56 6) was analyzed by a previously developed gas chromatographic (GC) method, using mass spectrometry (MS) with selected-ion monitoring (SIM) [27]. The method is based on basic extraction of cotinine from 2 ml of urine, into dichloromethane. After evaporation of the dichloromethane solution to dryness, 100 µl of toluene was added, prior to the GC-MS analysis. Trideuterated cotinine (CAS No. 97664–65–8) was used as an internal standard. Molecular ions (M) of cotinine and trideuterated cotinine (ion mass/charge (m/e) = 176 and 179) were monitored in the electron impact (EI) mode, and m/e = 177 (M + 1) and m/e 180 (M + 1) in the chemical ionization (CI) mode with isobutane. The standard deviation of the method was 5%, and the minimum detectable concentration, using SIM, was 2 µg/l in the EI mode and 0.2 µg/l in the CI mode. Creatinine in the urine samples was analyzed at the department of Clinical Chemistry, University Hospital, Lund, Sweden [27], and creatinine-adjusted concentrations of cotinine in urine were calculated and given as "µg/g crea". Unadjusted concentration of cotinine in urine was given as "µg/l".

Aircraft characterization

The same type of aircraft (Boeing 767–300), with a total number of 190 seats, was used on all flights. The smoking seats in tourist class (rows 21–39), are located near the aft galley and smokers in the Euroclass (rows 1–17) are located near the middle section.

The aircraft has a ventilation system normally providing approximately 50% fresh air and 50% recirculated air to the passenger cabin. Normally, the air exchange rate should be about seven turnovers per hour of fresh air in the cabin, or about 10 l of outdoor air per passenger and second. Occasionally, the pilot can shut off the recirculation fans for shorter periods, resulting in a 100% fresh air supply and an air exchange rate of about 12–15 turnovers per hour in the cabin. The air exchange rate on the flight deck is about 60 turnovers per hour. The engines in flight supply the fresh air. The air is conditioned by the air-conditioning packs, and ozone is removed by passing the fresh air through a catalytic ozone converter. The cabin air circulation system utilizes a pre-filter for larger particles, a high efficiency particulate air filter (HEPA) capturing particles of 0.3 µm and larger, and a charcoal filter to remove volatile compounds. The air-conditioning system does not contain any air humidification devices.

Statistical analysis

Differences in adjusted U-cotinine (µg/g crea) before and after flights were analyzed by the Wilcoxon matched-pair signed-rank test. The Mann-Whitney *U*-test was used to analyze differences in

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age and U-cotinine between groups. Statistically significant differences were found with and without creatinine-correction of cotinine. Differences in proportions was analyzed by Fisher's exact test for 2 × 2 contingency tables. The correlation between the number of smoking passengers on board, and increase in U-cotinine during the flight was analyzed by Spearman's rank correlation test. All statistical analyses were performed with the Statistical Package for the Social Sciences (SPSS), using two-tailed tests and a 5% level of significance.

Results

The median age for all 25 participants (5 male and 20 female) was 41 years (interquartile range 38–49 years). In total 18 C/A worked in the aft part of the aircraft, and 6 C/A and one pilot worked in the forward part of the aircraft. The proportion of males in each category, compared to all C/A in the airline, is given in Table 1.

All the subjects were non-smokers, living in dwellings without current smokers, and none used snuff or nicotine chewing gum. The median U-cotinine was 3.71 μg/g crea (2.4 μg/l) before departure and 6.37 μg/g crea (7.1 μg/l) after landing, a significant difference (Table 2). The maximum U-cotinine was 186 μg/g crea (105 μg/l) before departure and 221 μg/g crea (193 μg/l) after landing. The pilot, who had stayed the night in the crew hotel, had 5.75 μg/g crea (8.7 μg/l) U-cotinine before take-off, and 2.57 μg/g crea (2.9 μg/l) after landing. The 18 C/A in the aft galley had a significantly higher concentration of U-cotinine after landing than those 7 subjects working in the forward part of the aircraft (Table 2). In C/A working in the aft part, the median increase in U-cotinine was 3.71 μg/g crea (3.2 μg/l), (interquartile range 0.27–14 μg/g crea) during flight. In contrast, those seven subjects working in the forward part of the aircraft had no significant increase in U-cotinine during the flight (median increase 0.97 μg/g crea (0.5 μg/l), interquartile range 0.27–2.65 μg/g crea). Individual data on personal factors, type of flights, previous ETS exposure and cotinine in urine are given in Table 3.

U-cotinine before departure did not differ significantly between subjects exposed or not exposed to ETS in flights during the previous 3 days. Moreover, U-cotinine before departure did not differ between those with or without possible exposure to ETS during leisure hours in the preceding days. Finally, there was a tendency toward a higher increase in U-cotinine during the flight when there were more smoking passengers on board (Spearman's rho = 0.38; $P = 0.06$).

Table 1 Proportion of males and subjects among total study material ($n = 25$), compared with all C/A in the airline

Workplace location	No. of subjects	Proportion of males (%)	
		In our study	In all C/A in the company
Forward	7	57	76
Aft	18	6	6
Total[a]	25	20	20

[a] Significant difference in U-cotinine after landing between subjects working in forward and aft parts of the aircraft ($P = 0.001$ by Mann-Whitney *U*-test)

Discussion

Our investigation demonstrated that tobacco smoking in commercial aircraft may cause significant exposure to ETS among C/A working in the rear part of the aircraft, despite high air exchange rates in the aircraft and spatial separation between smokers and non-smokers.

In epidemiological studies, the results may be influenced by selection bias or recall bias. Such bias can be more problematic in studies on disease statistics or symptom reporting than in an exposure study based on biological monitoring. Our study was based on crew volunteers, restricted to subjects who were non-smokers living in non-smoking households. For practical reasons, we did not have the opportunity to record either the number of excluded subjects or the number of non-participants notfulfilling the selection criteria. Mean age and the proportion of males were similar to the mean age (41 years) and the proportion of males (20%) of all C/A in the airline, according to employment statistics from the company. This indicates that the study material was representative, with respect to age and gender, of C/A in the airline.

Table 2 Cotinine concentrations in urine (μg/g creatinine) in flight staff before take-off and after landing ($n = 25$)

Workplace location	No. in study	U-cotinine before take-off		U-cotinine after landing	
		Median	Interquartile range	Median	Interquartile range
Forward	7	2.74	0.62–4.25	3.54	2.57–5.04[a]
Aft	18	4.69	2.43–27[c]	12.2	5.51–36.4[a,c]
Total[a]	25	3.71	2.08–8.67[b]	6.37	3.98–19[b]

[a] Significant difference in U-cotinine after landing, when comparing subjects working in forward and aft parts of the aircraft ($P = 0.001$ by Mann-Whitney *U*-test)

[b] Significantly higher U-cotinine concentration after landing than before take-off ($P = 0.006$ by Wilcoxon matched-pair signed-rank test)

[c] Significantly higher U-cotinine concentration after landing than before take-off ($P = 0.01$ by Wilcoxon matched-pair signed-rank test)

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Table 3 Individual characteristics and U-cotinine (μg/g creatinine) levels for 24 C/A and one flight deck crew member who were exposed to environmental tobacco smoke during intercontinental flights (*aft* aft galley, *fwd* forward galley, *f/d* flight deck, *cph* Copenhagen, *kix* Osaka, *nrt* Tokyo, *pek* Beijing, *ewr* New York, *sto* Stockholm)

Subject no.	Age	Gender	Workplace location	ETS exposure in previous flights last 3 days	ETS exposure during leisure hours	Number of smokers	Destination	U-cotinine on board before flight	U-cotinine after flight
1	44	F	aft	no	no	normal	cph-ewr	3.72	14.2
2	41	F	aft	no	no	normal	cph-ewr	6.28	20.5
3	40	F	aft	no	no	normal	cph-ewr	2.92	6.73
4	34	F	aft	no	no	normal	cph-ewr	186	219
5	36	M	aft	yes	no	few	cph-ewr	2.65	7.17
6	38	F	aft	no	yes	many	cph-kix	109	72
7	30	F	aft	yes	yes	many	cph-kix	126	188
8	39	F	aft	yes	yes	many	cph-kix	9.2	6.37
9	54	F	fwd	no	no	few	cph-nrt	0.53	3.72
10	42	F	aft	no	no	few	cph-nrt	0.13	2.92
11	51	F	aft	yes	yes	few	pek-cph	72	71
12	58	F	fwd	yes	yes	few	pek-cph	3.10	3.54
13	43	F	aft	no	yes	many	cph-pek	5.31	5.58
14	31	F	aft	no	no	many	cph-pek	0.97	25
15	38	F	aft	yes	no	many	ewr-cph	8.14	12.7
16	38	M	f/d	yes	no	few	ewr-sto	5.75	2.57
17	47	F	aft	yes	no	few	ewr-sto	1.68	4.69
18	35	F	aft	yes	no	few	ewr-sto	2.65	4.25
19	53	M	fwd	yes	yes	few	kix-cph	4.25	5.22
20	45	F	aft	yes	yes	many	nrt-cph	4.07	17.8
21	41	F	aft	yes	yes	many	nrt-cph	1.77	5.31
22	40	F	aft	yes	yes	few	nrt-cph	12.3	11.9
23	56	M	fwd	no	no	normal	sto-ewr	2.39	5.04
24	55	F	fwd	no	yes	normal	sto-ewr	2.74	3.01
25	43	M	fwd	yes	yes	normal	sto-ewr	0.62	1.86

The low proportion of participating C/A working in the forward part of the aircraft, however, indicates an over-representation of subjects working in the aft part of the aircraft. Our total study material may thus lead to an overestimation of the average ETS exposure among C/A, but this problem was handled by dividing the material with respect to workplace location in the aircraft.

We could not demonstrate any significant influence of previous ETS exposure during earlier flights. This could be explained by the fact that we found only moderate cotinine excretion immediately after a smoking flight, even when the subject had worked in the most exposed part of the cabin. Moreover, the crew had a service schedule with 1–3 days of vacation between the intercontinental flights with ETS exposure, resulting in decay of cotinine from the body fluids. The lack of a significant relation between cotinine and estimated ETS exposure from restaurants during leisure time, when staying in hotels abroad, could be due to lack of precision in this exposure estimate. It is, however, also possible that our non-smoking participants chose to stay in locations with a low amount of ETS exposure even when staying in countries with a high degree of smoking in public places. Smoking in the crew bases is allowed in some of our departure countries (Denmark, Japan and China), but this exposure was not found to be related to U-cotinine levels before take-off. This is probably due to the short duration of stay in the crew base (about 1 h), on the way from the dwelling or hotel to the aircraft.

Thus, we found a significant increase in U-cotinine during flight only among those working in the aft part of the aircraft. This is in agreement with our earlier hygiene measurements on the same type of aircraft, showing a higher degree of ETS-related air pollution in the aft galley than in forward galley [19]. The average cotinine concentration in urine after landing (6.37 μg/g crea; 7.1 μg/l) was similar to earlier studies on ETS-exposed occupational groups. Willers et al. [33] found median U-cotinine of 3.1 μg/l among ten police interrogators, 16 μg/l among five restaurant staff and 5.9 μg/l among cafe staff. Skarping et al. [27] found cotinine levels of 30 μg/l after car driving with smokers. Husgafvel-Pursiainen et al. [14], found a mean concentration of 56 μg/l in waiters working in restaurants in Finland. In our study the peak cotinine concentration may have been missed, thus the differences before and after the flight may have been underestimated [21].

Three of our participants had initial U-cotinine levels indicating infrequent smoking or obvious exposure to ETS during the past few days. The maximum U-cotinine in our study was 219 μg/g crea (193 μg/l), within the suggested discriminatory values of 60–500 μg/l between smokers and non-smokers [1, 34]. All the other participants were well below these suggested discriminatory values. Other sources of nicotine exposure include some food, (primarily from the family Solanaceae), e.g. eggplants, potatoes, tomatoes and some tea plants [3, 13]. However, considering the average and maximum daily consumption, U-cotinine values from food are negligible

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[33]. Further, we have no reason to believe that differences in food consumption pattern prior to or during flight could explain the increase in U-cotinine during flight related to work in the forward part of the aircraft.

Since smoking in commercial aircraft may cause involuntary exposure to ETS, it should be avoided. This is in agreement with the conclusions from the International Civil Aviation Organization (ICAO) and the Acrospace Medical Association [28], that all airline flights should be smoke free.

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